Nanostructured solar cell prepared by chemical spray pyrolysis method

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Introduction

The most widely used designs of solar cells based on ZnO nanostructures include addition of a light absorbing material such as organic dyes, polymers or inorganic extremely thin absorbers (ETA). Recently our group presented the technology for the preparation of ZnO nanorod arrays by chemical spray pyrolysis (CSP) method [1, 2]. Conversion efficiencies in the order of 2.5 % have been recorded for ETA solar cells where both ZnO rods and $CuInS_2$ absorber were prepared by chemical spray [3, 4]. We present the results on development of the CSP deposited ETA-cells. We focus on the effect of In_2S_3 buffer layer thickness and the length of the ZnO nanorods on solar cell output characteristics.

Preparation

$ZnO_{rod}/In_2S_3/CuInS_2$ type nanostructured ETA solar cells were prepared by low cost, in-line chemical spray pyrolysis (CSP) method. The cells were realized on ZnO nanostructured layer composed of nanorods (length ~500-1000 nm, diameter 100-300 nm). The length and thickness of the rods were adjusted by changing the concentration of zinc source ($ZnCl_2$) in an aqueous spray solution. In_2S_3 buffer layer was deposited onto ZnO nanorods before the absorber layer was applied. The thickness of buffer layer was varied with the amount of the spray solution. CuSCN/Au or carbon were used to make the back-contact to the cell, transparent conductive oxide (ITO) was acting as the front-contact.

Characterization

Current-voltage (I-V) characteristics in dark and under the halogen lamp illumination (100 mW/cm^2); and external quantum efficiency (EQE) spectra was obtained. EQE vs voltage dependence was recorded via biased solar cell.

Results on effect of buffer layer thickness

A loss of the EQE is observed in the high energy region of the spectrum in case of thicker buffer layer, indicated by cell type 2 and 3 (Fig. 1). However, thicker buffer layer results in the improvement of the I-V characteristics: V_{OC} from 98 mV to 410 mV (from type 1 to 3), J_{SC} from 9.9 mA/cm^2 to 15 mA/cm^2, FF from 31 % to 59 % and conversion efficiency from 0.3 % to 3.5 % resulting in an overall EQE increase (not shown). The relative decrease of EQE could be explained by higher light absorption in the thicker buffer layer with bandgap of ca 2.2 eV. However improvement of the I-V characteristics may be attributed to the reducing of short circuiting due to more conformal covering of the ZnO nanorods by buffer layer. The highest conversion efficiency 3.5 % has been recorded from a small contact area (0.04 cm^2) on a cell with the thickest buffer layer (type 3). The cell is based on rods with length of ca 500 nm.

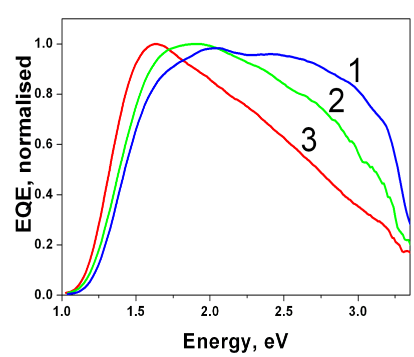

Figure 1: EQE spectra of the CSP deposited ETA solar cells. The thickness of In_2S_3 buffer layer increases from cell type 1 to 3.

EQE vs voltage dependence shows that reverse bias (indicated by a negative sign in Fig. 2) does not increase EQE in the low energy region, however shows a minor increase in the high energy region. It may be speculated that the absorber is thereof fully depleted, however reverse bias results in the expansion of the depletion layer into the buffer layer. This seems to be confirmed by a similar tendency of the EQE induced from different buffer layer thicknesses (Fig. 1).

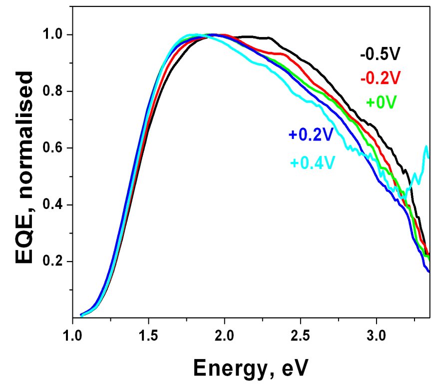

Figure 2: Normalised EQE vs voltage dependence of the CSP deposited solar cell. The thickness of the In_2S_3 buffer layer corresponds to cell type 2 (Fig. 1).

Results on effect of ZnO nanorod length

The use of ZnO structured layer composed of nanorods with length of ~500 nm instead of a planar film increases the current density from 5-6 mA/cm^2 up to 11-13 mA/cm^2 with no significant reduction in V_{OC} and FF. Further increasing the rod length leads to higher current densities (up to 16-17 mA/cm^2) accompanied by decreased V_{OC} and FF (Fig. 3). The possible explanations may be increased interface recombination, non-optimized local thickness of the buffer and absorber layer and short circuiting between back and front contact due to the increase of uncovered areas of the substrate in case of longer ZnO rods.

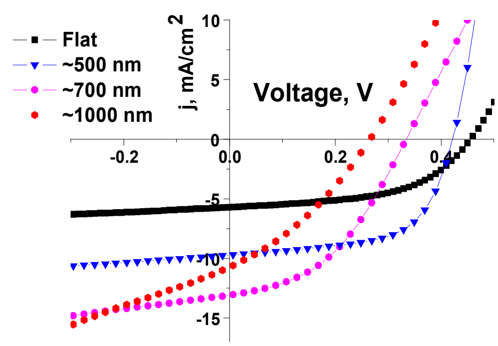

Figure 3: I-V characteristics of the CSP deposited solar cell. The length of the ZnO nanorods is varied. "Flat" indicates the absence of ZnO rods, i.e. compact layer of ZnO.

Summary

Effect of the buffer layer thickness and ZnO nanorod length (500-1000 nm) were studied on the I-V characteristics and EQE spectra of the CSP deposited ETA solar cell. Thicker In_2S_3 layer increases V_{OC} and FF, however induces certain spectral loss due to light absorption. The highest conversion efficiency 3.5 % has been recorded on a cell with the thickest buffer layer. The optimum length of ZnO nanorod length at present, for the application in ETA solar cell, is ca 500 nm.

Acknowledgement

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References

[1] M. Krunks, T. Dedova, I. Oja Açik, Thin Solid Films **515** (2006) 1157.
[2] T. Dedova, O. Volobujeva, J. Klauson, A. Mere, M. Krunks, Nanoscale Res. Lett. **2** (8) (2007) 391.
[3] M. Krunks, A. Katerski, T. Dedova, I. Oja Acik, A. Mere, Sol. Energy Mater. Sol. Cells **92** (2008) 1016.
[4] I. Oja Acik, A. Katerski, A. Mere, J. Aarik, A. Aidla, T. Dedova, M. Krunks, Thin Solid Films **517** (2009) 2443.